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WEAR BEHAVIOR OF FE-Cr-V BASED HARD FACING ALLOY ON ASTM A105 STEEL

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ABSTRACT

Dynamic contact surfaces life rate depends on various factors, majorly it is influenced by wear between contact surfaces. Hard facing is one of ancient technique used to improve mechanical properties, majorly surface properties of contacting surfaces and reduces the internal stress. The present investigation is on the influence of multilayer hard facing on abrasive wear compared to monolayer hard facing. Composition of Fe with the addition of chromium and vanadium based hard facing coatings are deposited on ASTM A 105 STEEL in form of single layer and multilayer depositions by using Shielded metal arc welding. Microstructure investigations stated that homogenous dendrite colonies are formed on both layers. The monolayer exhibited poor abrasive wear resistance as compared to multilayer depositions and more surface cracks and voids are formed. The wear rates of depositions are investigated in the form of volume loss and mass loss. Increase in content of carbon can increase the hardness and the binding strength of the layers and reduce the effect of abrasive wear.

KEYWORDS: Hard facing, Multilayer, Monolayer, Dendrite Colonies, Carbide Volume Fraction & Abrasive Wear

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Original Article

INTRODUCTION

Hard facing of material is a special coating of a layer over a base material for improvement of properties of material. It is one of the surface treatment process mainly used to reduce the effect of wear and oxidation on surfaces at elevated temperatures and corrosion attacks to extend their service life of materials [1]. The wear resistance depends on the factors like hard facing alloys, matrix materials, matrix hardening agents, temperature, erodent and abrasion particles [2]. Wear is disintegration of material caused mainly due to rubbing surfaces of moving parts and environment effects. Wear not only depends on materials properties but also on parameters like load and friction [3]. Friction is the resistance to movement of one body over body as it plays a significant role in daily activities and mostly in industrial processes. It provides continual sliding movements between surfaces results in wearing of materials [4].

Enormous investigations are carried out for improving the properties of materials to reduce of wear. Several advantages are obtained by hard facing to worn parts like repairing cost of these parts are economically cheap, rate of time for repairing is decreased and life period of parts are extended such as coal hopper linings, marine equipment linings and in Aero-automobile applications. Recent investigations indicated that microstructures, grain size, porosity and coating thickness also influence the rate of wear [8]. Multilayer deposition is layering of hard facing alloy on primary layer. It consists of more than two layers which can reduce the porosity while layer formation and relives the internal stresses of the material. Compared to monolayer coatings multilayer coatings are superior resistance to wear.

Multilayer depositions result in greater binding strength and hardness as the carbon content is increased with high fraction of carbide formations results in excellent resistance to external load and wear. Abrasive wear depends on distribution of volume of carbides and toughness of layer formed [4].

Good wear resistance is offered by multilayer than single layer. Morphology study stated that more wear and cracks formation in single layer than multilayer [5]. Most commonly Fe based hard facing alloys are used with major additions of carbon, chromium and nickel substrates to improve the surface properties of materials [7]. Material loss from hard-faced coating was by formation of lips followed by their fracture which initiated in the interdendritic regions [11]. Coating of Fe based hard facing is cheaper than other coatings and also provides a good resistance at elevated temperatures. Mainly high chromium based hard facing shows good resistance to oxidation and corrosion [7]. In this investigation a composition of Fe-Cr-Ni-C based hard facing alloy is coated on ASTM A 105 steel in single and multilayer coatings. A comparison of wear behavior is carried out on single layer over multilayer and brittleness and the hardening properties of materials are one of the major factors influences the effect of wear.

EXPERIMENTAL DETAILS

Material Composition

A composite hard facing alloys coating can achieve a wide range of properties. The hard facing alloy and substrate compositions are reported in Table 1.

Table 1: Chemical Composition of Hard Facing Alloy and ASTM A 105 Steel

Material	Chemical Composition						
	C	Mn	Cr	S	Mo	Others	Fe
ASTMA 105 Steel	0.30	0.80	-	0.40	-	0.35 Si &0.40P	Remaining
Hard facing Alloy	0.70	0.40	7.80	-	0.80	0.45 Si & 0.70 V	Remaining

SPECIMEN PREPARATION

In this process Shield metal arc welding process (SMAW) is used to deposit the hard facing alloy on ASTM A 105 steel (cylindrical rods) homogenously. It is one of the cheapest processes for layering of hard facing materials on substrates [13]. The hard facing alloy electrodes of 4mm diameter are deposited on tip of substrate in form of layers of each length 2mm (approximately) as shown in below in Table 2.

Table 2: Design Details of Pins and Layer

Specimen	Diameter (mm)	Layers deposited	Length (mm)
Sp- 1	8	1	40
Sp-2	8	3	40

Table 3: Input Parameters of Welding and Hard Facing Electrode

Welding Parameters and Electrode Specifications			
Voltage (Volts)	**Current (Amps)**	**Length of electrode (mm)**	**Diameter of electrode (mm)**
30	140	450	4

The hard faced pins were machined in the form of pins (cylindrical rods) by turning and grinding operations are carried with dimensions [14] as shown in Table 2. Input welding parameters of SMAW are reported in Table 3.

Figure 1 reports about modelling of multilayered pin. The surface roughness test was carried out on Mittoyo surface roughness tester SJ-301 and the surface roughness was 0.32 micrometers. The hardness test was carried on Rockwell hardness

and reported that average hardness of three trials for single layer and multilayer were 75 HRB and 82 HRB under 100 kg load.

Figure 1: Modeling of Multilayer Hard Facing

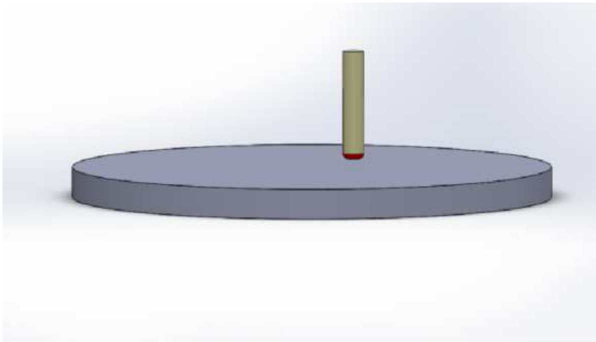

Figure 2: Modeling of Pin on Disc

Hard faced samples were prepared in the standard manner for examination of morphology [7]. Samples were polished with disc polishing with alumina powder and Sic abrasive grit papers of grades A, B, C, D were used. Nital (2% of Nitric acid and 98% of Ethanol) is used as etching agent. Microstructure and the wear surface structure of hardfaced layers were investigated on top surface under computerized optical emission microscope with digital photography[2].

WEAR TEST

The wear test was carried out on Pin on disc wear tester of TL20R with surface contact at room temperature. The wear rate, time, load and temperatures data are recorded by computerized data recording system emphasized with Ducom software and results are obtained in Origin Software. Wear test is carried out according to ASTM G99-95a standards for investigation of the hard facing alloys [9].

In this test the specimen is pressed against the rotating disc. Friction developed due to rubbing action between contacting surface of pin and disc resulted in abrasive wear. Figure 2 shows the modelling of surface contact pin to rotating disc. As the wear test was carried out for both the specimens parameters were kept constant and reported in Table 4. The sliding velocity of disc was 0.4 m/sec, weight of specimens measured before and after the wear test which resulted in mass loss of specimen. Volume losses of pins are also reported in Table 5. Worn out surfaces structures of both specimens were observed in optical emission microscope.

Table 4: Input Parameters used for Wear Test

Wear Test Parameters	Speed of disc (Rpm)	Load (N)	No. of Revolutions	Track Diameter (mm)	Disc Type & Hardness
	300	30	2000	25	Annealed S. S alloy & 56 HRC

RESULTS AND DISCUSSIONS

Microstructure and Hardness Characterization

The microstructure of both specimens showed different microstructure as the composition of multilayer is differ from monolayer due to layers placed over them. Figure 3 shows microstructure of monolayer in austenitic phase with enrich in iron matrix with chromium carbides. It showed that homogenously distribution of carbides which formed are dark phases in microstructures are the Fe carbides. It shows the formation of dendrite structure distribution of carbides.

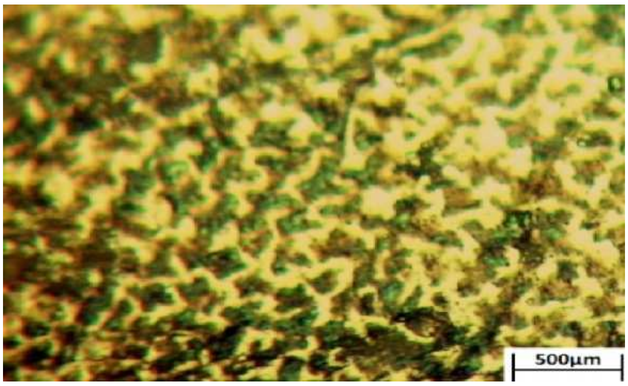

Figure 3: Microstructure of Mono-Layer Hardfacing

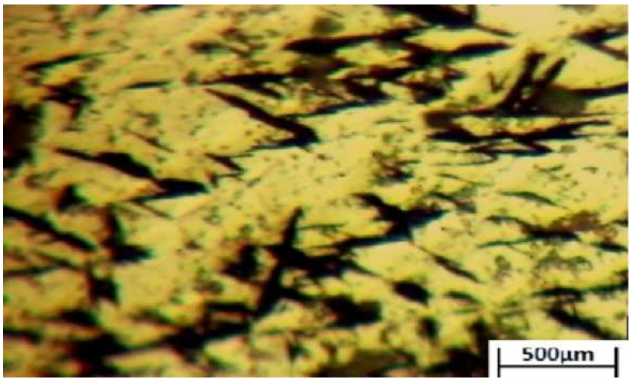

Figure 4: Microstructure of Multi-Layer Hardfacing

Compared with mono layer to multilayer the composition of carbon increased and volume of carbides are high and showed higher binding strength. Figure 4 shows microstructure of multilayer which is having equi-dendritic and needle like structures. It shows more precipitations of vanadium are more as compared to monolayer. Lathe facing and grinding operations made surface very hard, these are some of the parameters due to which made differ in hardness results and it showed in martensite phase. This is formed due to plastic deformation strain formed due to machining and finishing operations. Increase in carbon content can increase the hardness but also increases the brittleness of the material but on other way it can form more carbides which resists towards abrasive wear. It concludes that hardness plays an efficient role in wear resistance within certain limit. Figure 5 Shows the comparison of hardness between mono layered and multilayered specimens.

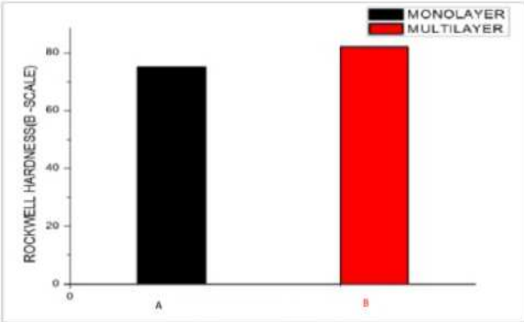

Figure 5: Hardness of Mono and Multi Layers

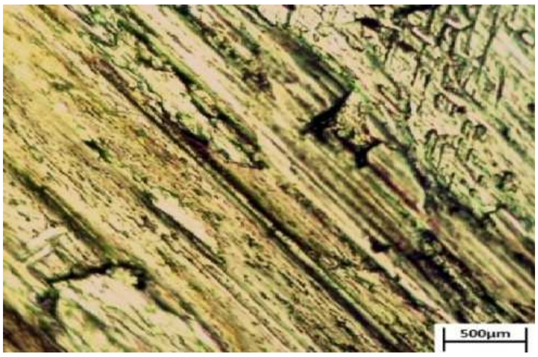

Figure 6: Worn Surface of Multilayer

CHARACTERIZATION OF WEAR BEHAVIOUR

The wear test is conducted for both the specimens with constant parameters on the pin on disc as reported in Table 4. The wear behavior is mainly dependent type of contact surfaces, surface roughness, sliding speed and environment conditions [4]. It also depends on the carbide volume fraction such that increase in carbides increases the hardness of materials results in good abrasive wear resistance. Figure 6 shows surface morphology of multilayered hard facing showed a plough nature and some brittle properties.

Temperature and load can influence the wear behavior such that oxide layers can form during sliding on surfaces and deep uneven cracks [8]. In multilayer deposition resulted in mild wear nature with worn surfaces but in case of monolayer had severe abrasive wear with formation of wear debris. Monolayer hard facings howed poor abrasive wear resistance compared to multilayer, cracks are formed on surface, chips and flake ejections are appeared, it is showed in Figure 7. The formation of internal voids and accumulation of wear out chips in cracks can also increase the abrasive wear.

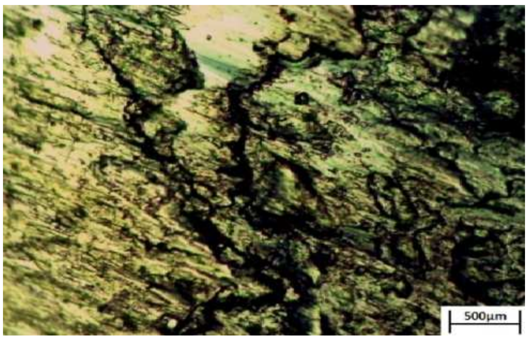

Figure 7: Worn Surface of Monolayer

Figure 8(a) and figure 8(b) shows the multi and mono layer wear rate with respect to the time. As shown in this results states that at different intervals of time the wear rate got peak due to accumulation on worn out chips in voids formed in the surfaces and as the time increased wear rate get dropped.

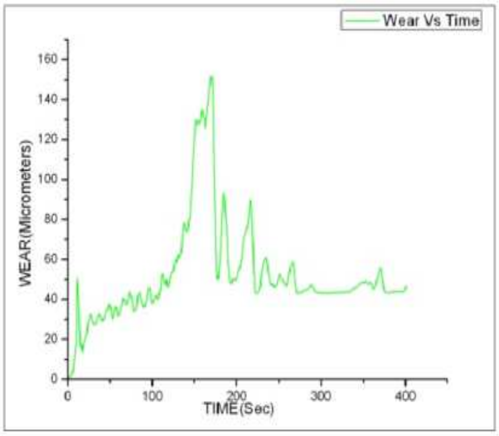

Figure 8(a): Wear vs Time under Load Applied on Multi Layer Deposition

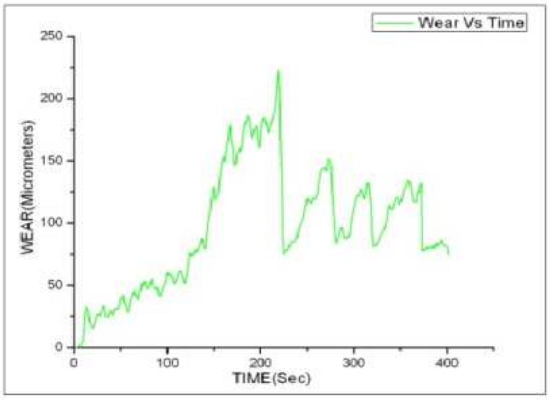

Figure 8(b): Wear vs Time under Load Applied on Mono Layer Deposition

The crushing of hardened chips may get welded on surface and these resulted in formations of deep scars. The cracks which formed on the materials due to its brittleness of materials and during the wear formations of cracks propagate in both parallel and perpendicular directions. The Figure 9 shows the comparison of wear rate of both mono and multi layers.

The wear rates of both the specimens are calculated in form of mass and volume losses of pin. Wear leads to substantial loss of mass or dimensional loss. The mass loss of specimen is calculated as difference obtained from the weights noted before and after the wear test.

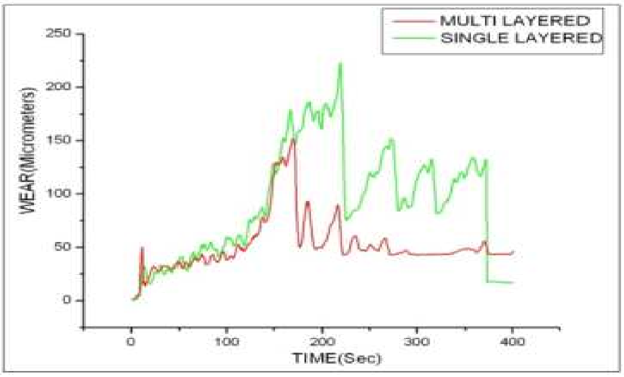

Figure 9: Comparison of Wear vs Time under Load Applied on Mono and Multilayer Depositions

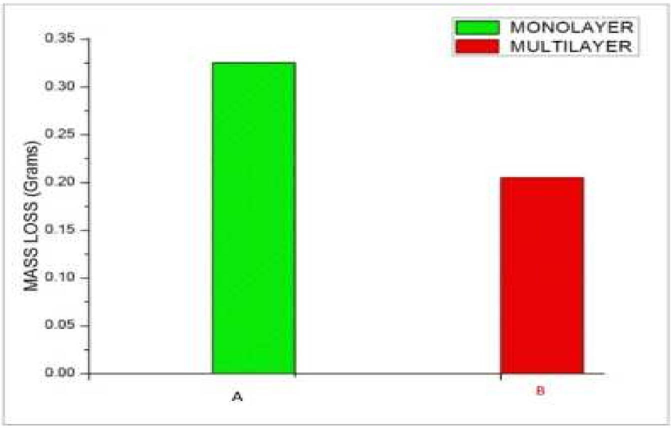

Figure 10: Mass Loss of Mono and Multi Layers

Similarly the volumes loss of pin is also calculated as per standards ASTM G99-95a shown in below equation [1]. Figure 10 shows the mass loss of pins and results are tabulated in Table 5.

$$\text{Volume loss of pin} = \frac{\text{Mass Loss (g)}}{\text{Density (g/cm}^2\text{)}} \times 1000 \qquad (1)$$

Table 5: Volume Loss of Pins

S. No	Specimens	Volume loss (mm^3)
1.	Single layered	36.03
2.	Multilayered	21.28

CONCLUSIONS

- Multi layering can reduce the internal void formations and external surface defects and results in greater binding strength and hardness as the carbon content is increased with high fraction of carbide formations results in excellent resistance to external load and wear.
- Increase in carbon content increase the hardness but also increases the brittleness of the material due to increase in formation of carbides volumes which resists towards abrasive wears[2]. In some cases, the lathe operations for surface finishing under dry conditions are also responsible for hardening of surface layers.

- The worn surfaces of monolayer showed high rate of abrasive wear and more surface cracks. Severe ploughing nature and crushing of hardened chips which accumulated in voids and get welded on surface resulted in formations of deep scars and welded regions on rubbing surfaces. Due to above reasons sudden increase in wear rate was reported. To avoid the chip formations Ten-alloy may be preferred.
- Morphology of multilayer stated that homogenous colonies of carbides are formed as compared to monolayer. In multilayer homogenous distribution of carbides and whitish precipitations are formed. Addition of chromium resulted in decrease of formation of oxide layers.
- Mass loss and Volume loss of pin stated that as compared to multilayer the mono layer resulted in poor resistance to abrasive wear.

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